Chapter Four:

Concrete Placement

Although this Chapter is called “Concrete Placement” it will cover more than just the placement operation. The major topics to be discussed are:

- Classes of concrete,
- Concrete plants,
- Preparations for concrete delivery,
- Field tests,
- Concrete placement,
- Concrete finishing, and
- Curing methods

While the first two items primarily concern technicians of concrete plants, Certified Technicians need a basic knowledge of the requirements for concrete used in bridge construction and the plants that produce it. Such an understanding will help to form a cooperative relationship between the technicians at the plant and the ones in the field.

Classes of Structural Concrete

Structural concrete is produced in three classes: A, B, and C. The differences between the classes are in cement and aggregate contents and water/cement ratios.

Bridge construction often requires the use of all three classes. For example, the plans may call for Class B concrete for the footings, Class A for the piers and bents, and Class C for the decks and railings. The Notes section of the General Plan sheet will list the classes of concrete to be used, as will the Bill of Materials section on the detail sheets. In most cases, the contractor may substitute Class C for Class A and wither Class A or Class C for Class B.

Materials

The materials used in the production of structural concrete will include combinations of the following:

- Fine and coarse aggregates;
- Portland cement;
- Fly ash (a coal by-product);
- Water; and
- Admixtures, including retarders, accelerators, water reducers, and air entraining agents.

All aggregates used in the structural concrete should be from the Certified Aggregate Producer List (CAPP), issued by Indot Materials & Tests. Certified Technicians are more concerned with plastic concrete and concrete as a finished product.

Concrete Plant Inspection

Types of Plants

The department categorizes concrete plants as *captive* plants or as *commercial* plants. Captive plants are usually temporary and used primarily to produce concrete for a specific State project. When the project is finished the plant is disassembled and moved. Commercial plants, on the other hand, are permanent installations and may serve many customers.

Concrete plants are inspected and certified by the Division of Materials and Tests. Commercial plants are inspected once a year. Captive plants are inspected at the beginning of each construction season and whenever they're moved to a new location.

A check list of requirements for plant certification is included in the appendix.

The Plant Technician

There are two reasons for having technicians at concrete plants. The first is to insure that the State receives the quality of materials the contractor has agreed to supply, and the second is to insure those materials are delivered in the proper quantities.

Plant technicians are responsible for observing all weighing, batching, and mixing operations, except when mixing takes place away from the plant site. They must make sure that all materials have been sampled, tested, and approved. The plant scales used for batching cement and aggregates have to be checked for accuracy twice a day.

Plant technicians should try to create and maintain a cooperative relationship with the contractor and plant personnel. Any experienced Certified Technician knows the best way to do that is to be prepared for work: know the requirements as well as possible, and when in doubt, find the answer or ask for help. For a more complete picture of the plant technician's duties, refer to Form IC 739, the plant technician's daily check list. A copy of the check list is included in the appendix.

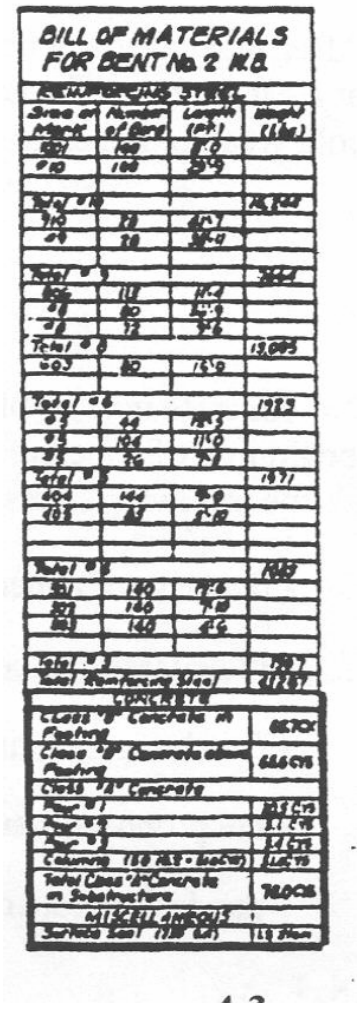
Preparations for Concrete Placement

The smooth delivery of concrete to the jobsite is critical. Delays in the delivery of the concrete or during the placement operation can cause problems that will be time consuming and costly to resolve. The Certified Technician, the contractor, and the concrete plant technician have to work together to insure getting the right concrete delivered on time and in the necessary quantities.

Plan Review

Preparing for the delivery of concrete begins with a review of the plans. Double check the class or classes of concrete required. Use the Bill of Materials section of the detail sheets to find the estimated quantities for each class of concrete. Remember, substitutions of a higher class of concrete are generally allowed, but never permit the contractor to substitute an inferior class of concrete for the one called for in the plans.

The detail sheets also provide important additional information about the concrete pour such as the pour sequence and the locations and dimensions of construction joints and keyways.


BILL OF MATERIALS
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Site Preparations

The Certified Technician should insure that the site has been adequately prepared for concrete placement. Such preparations include:

- Excavations have been dewatered;
- Forms have been checked for adequate bracing and proper elevations and alignment;

- Chamfer strips have been installed and are in good shape;
- Trash and debris have been removed from all forms;
- Reinforcement has been tied securely and checked for proper clearance and spacing; and
- The contractor has adequate manpower and equipment to handle the pour—sufficient number of vibrators, including backups.

Weather Restrictions

The technician should know the weather forecast for the concrete placement operation. Weather conditions can influence everything from the timing and method of concrete delivery and placement to postponing the operation altogether. Ideally, concrete should be placed in temperatures between 50 and 90 degrees Fahrenheit, when there's no threat of rain, and when steps have been taken to protect the concrete from excessive wind.

In general, when the temperature is 35 degrees or below, the temperature of the concrete should be between 50 and 80 degrees at the time of placing. The contractor may heat the water and/or aggregates used in the concrete mix to achieve that range of temperatures, but that heating has to be done in accordance with the Specifications for cold-weather concrete. The technician should use a dial thermometer to check the concrete temperature whenever it's suspected to be near the Specifications limits.

Concrete Delivery

No concrete may be placed without an Certified Technician on the job and one at the concrete plant. Prior to the beginning of concrete delivery, the Certified Technician should contact the plant technician to double-check the following items:

- The class of concrete to be used;
- The quantity of concrete needed for the pour;
- The slump and air content requirements;
- The proposed starting time of delivery; and
- The desired rate of delivery.

Delivery Equipment

Concrete is typically delivered to the job site in mixer trucks, agitator trucks, or in non-agitating equipment. All delivery trucks must comply with the equipment Specifications outlined in Section 702.

Mixer trucks are designed for mixing concrete at or on the way to the job site. For this reason, mixer trucks always have a water tank on board and a measuring device that is capable of controlling the amount of water that is added to the mix. Agitator trucks deliver *ready-mixed* concrete; any water on board is for cleaning purposes only, not for mixing.

When mixer trucks are used, the following items should be checked:

- Manufacturer's rating plates are in place and legible;
- Revolution counters are operating properly;
- Mixing speed and a number of revolutions are in compliance with the Specifications. The number of revolutions of the drum at mixing speed must be between 70 and 100;
- Trucks are operated at or below their rated capacity.
- Old concrete is removed from drum; and
- Wash water is properly drained from the drum

Delivery Tickets

As the concrete is delivered to the job site, the Certified Technician collects a delivery ticket from each truck.

When the concrete delivered to the job site is produced at a commercial or captive plant, the producer's ticket is used to document delivery. The producer's ticket for the *first* load of each class of concrete delivered *each* day should contain the following information:

- The correct contract or project number;
- The correct date;
- The producer's name;

- The plant location;
- The contractor;
- The class of concrete delivered;
- The weights per cubic yard of all materials, including admixtures;
- The number of cubic yards delivered;
- The time of day that the water and cement were combined; and
- The plant technician's signature.

After the first load is delivered, the producer's name, the plant location, the contractor, and the weights of the various materials used in batching may be omitted from the producer's tickets for the rest of the day or until the mix design is changed. If the mix design is changed, the ticket for the first load of the revised mix should indicate all changes.

Field Tests

Conducting and/or observing concrete field tests is one of the most important duties of a Certified Technician. Typical field tests include slump, air content, yield, and water/cement ratio. The equipment used to conduct the tests should be clean, in good shape, and capable of providing accurate results. The air meters used in air content tests and the scales used in yield tests must be calibrated and approved. All test equipment is provided by the Division of Materials and Tests.

The procedures for conducting slump, air content, and yield tests are detailed in Sections 45 and 47 of the Department's *General Instructions to Field Employees*; procedures for flexural strength tests are found in Section 44. The required frequency for conducting all tests is given in the *Manual for Frequency of Sampling and Testing*. That frequency, however, is a *minimum* and may be increased as specified by the plans, the special provisions, or by the Engineer. The following is a brief description of the purpose of each test; detailed, illustrated instructions, of common field tests procedures are included in the appendix.

Slump tests are performed to determine the consistency of fresh concrete and to check the uniformity of concrete from batch to batch. Typical specification limits for slump for *structural* concrete are between one to four inches. Unacceptable slump measurements usually indicate improper mix proportions, especially in water content. Don't allow contractors to add water simply to make the mix easier to pour; any such change to the mix design needs prior approval.

Air content tests are performed to determine how much air is contained in the concrete. In most cases, air has been purposely added to or “entrained” in concrete to make it more durable through the use of an air-entraining admixture. Allowable air content can range from five to eight percent, depending on the maximum size of the aggregates used in the mix. Results outside the specified limits indicate a need to adjust the amount of admixture in subsequent batches.

Yield tests are performed to determine the weight per cubic foot of fresh concrete which in turn is used to determine the cement in barrels per cubic yard of freshly mixed concrete. Yield tests are *not* used to check on the batching of any one mix component.

Flexural Strength--performed to determine when forms and/or falsework can be removed from a structure or to determine when a structure can be put into service. This test involves placing fresh concrete in a beam mold and allowing it to set and cure under the same conditions as the concrete used in the structure. The concrete is then removed from the mold and broken in a controlled environment by a beam breaker. The test results can then be used to make certain assumptions regarding the strength of the concrete used in the structure.

Water/cement Ratio--is the ratio of the total amount of free water in the aggregates, including all free water in the concrete, to the amount of cement in the concrete. The ratio must not exceed the values in Article 702.02.

Recording Test Results

The results of slump, air content, and yield tests are recorded and submitted on Form IT 652; flexural strength tests are documented on Form IT 571A; and water/cement ratio is recorded on Form IT 628. Copies of these forms can be found in the appendix as well as required procedures for the field tests.

Concrete Placement

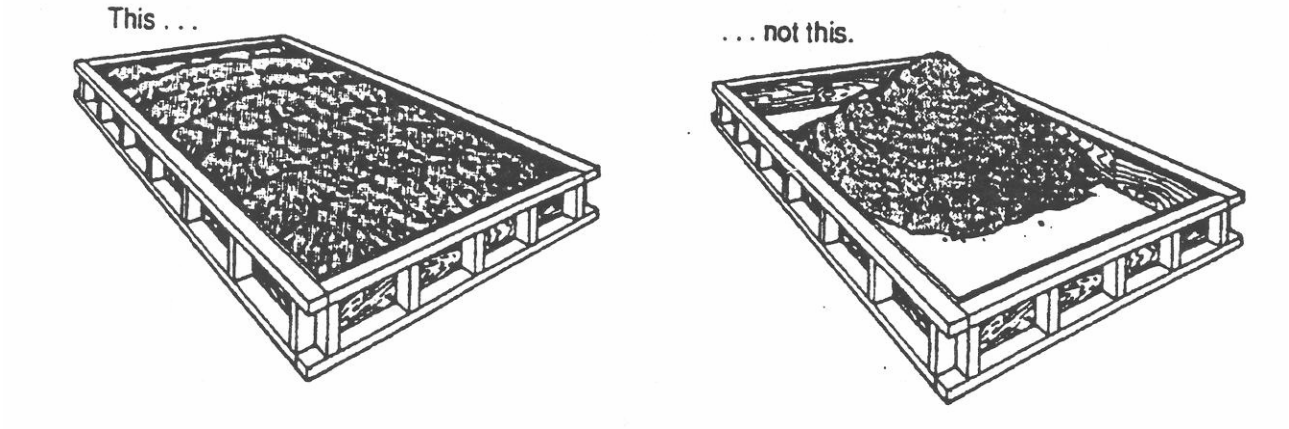
Compared to the preparations leading up to the pour and the testing, the actual placement operation is relatively simple. But there are still things that can go wrong.

Segregation

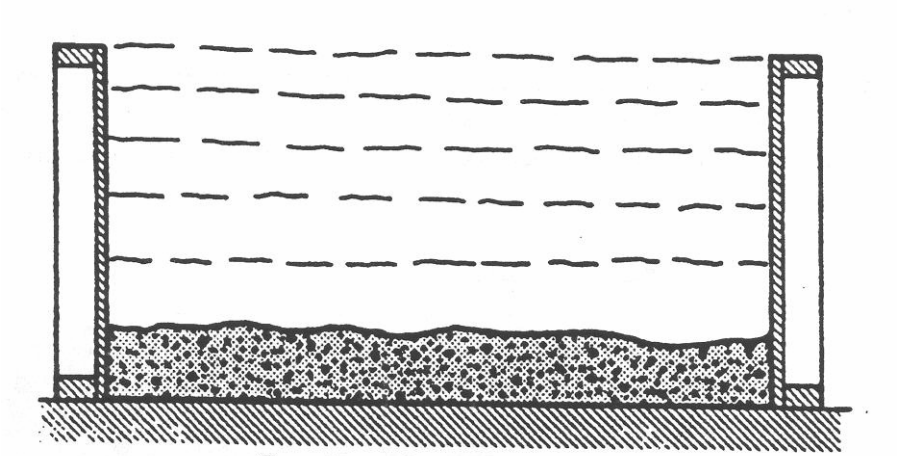
Segregation occurs when the coarse and fine aggregates used in the concrete separate and become unevenly distributed throughout the mix; the larger coarse aggregate sinks to the bottom while the fines rise to the top.

Segregation always leads to an inferior quality of concrete. For the most part, however, segregation can be prevented with the use of proper placement equipment and techniques.

Concrete should be placed as close as possible to the location it will occupy in the structure. It shouldn't be dumped in a central location and allowed to spread out on its own.

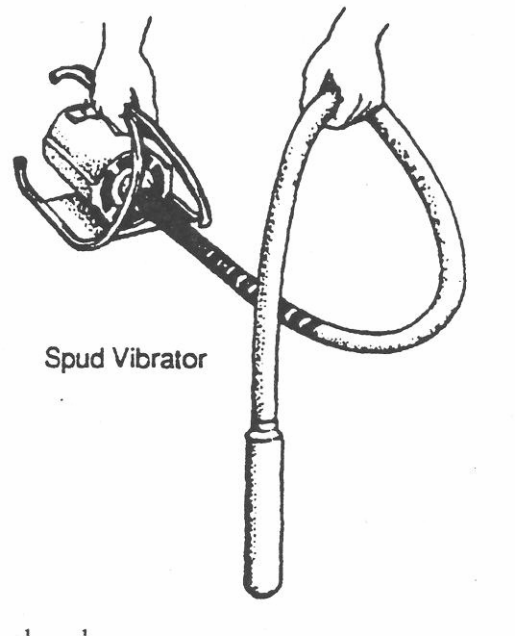


When possible, concrete should be deposited in layers, no more than 24 inches thick. Care should be taken, however, to place each successive layer before the preceding layer has taken its initial set, usually 45 minutes to an hour, depending on the temperature. Too much time between the placement of layers will usually result in a "cold joint", a weak line of separation between the layers.


Even layers keep the mix uniform.

Dropping concrete from too great a height causes the finer particles in the mix to splash away from the larger, heavier particles. In addition, the force of the mix striking the re-steel can shift bars out of position. The *maximum* drop height or allowable free fall is five feet. Hoppers with flexible chutes called *tremies* should be used to funnel the mix down into the tall, narrow forms. Workers can be stationed down inside the forms to move the chutes around to insure an even distribution of the mix. The hoppers should not rest on the re-steel; they should be supported by the formwork.

Consolidation of Concrete

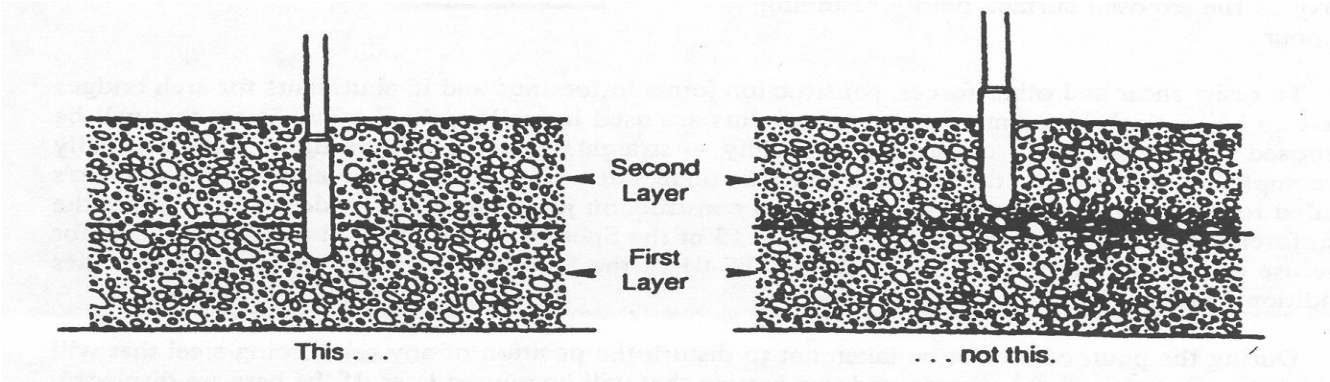


Fresh concrete naturally contains air pockets or voids. If it were left that way the finished product would have a rough surface and be of questionable strength. To eliminate voids and to insure a good bond to the re-steel, the concrete must be *consolidated* to a uniform density.

The most common method of consolidating concrete is by *vibrating* it with a portable "spud" type vibrator. Most vibrators have an effective radius of 18 inches all around; once they're inserted, they'll consolidate an area three feet in diameter.

Although it's a simple operation, vibrating concrete is often performed incorrectly. Below are some points that will insure a good job.

- Vibrating should be done immediately as the concrete is placed.
- Vibrators should be inserted and withdrawn vertically. They should not be dragged through the concrete. That can cause segregation.
- Vibrators should be inserted and withdrawn quickly; five seconds or less is a good rule of thumb. Over-vibrating one are will force the finer aggregates to the top and drive the larger aggregates toward the bottom.
- When concrete is poured in layers, the head of the vibrator should penetrate through the top layer and partially through the layer underneath.



- The workers should avoid contacting the re-steel with the vibrator as that breaks the bond between the steel and the concrete.

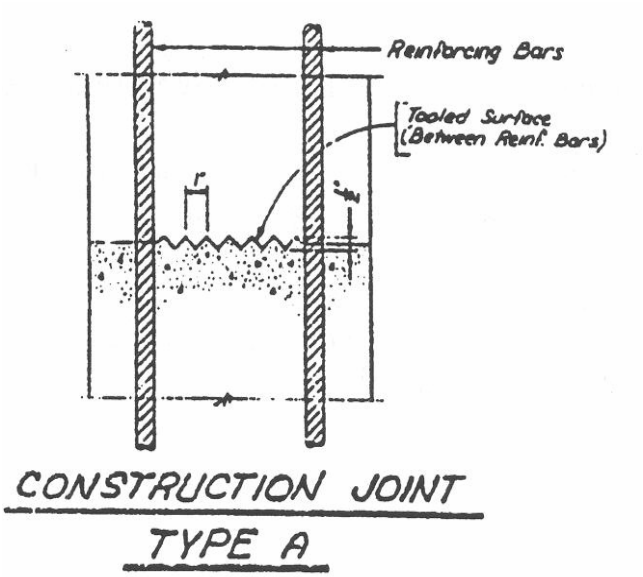
- The workers should avoid contacting the form walls with the vibrator as that may loosen the forms; it may also cause honeycombing of the concrete surface.

- The contractor is required to have a backup vibrator on hand for larger pours in case of equipment problems.

Construction Joints

The purpose of a construction joint is to joint a section of fresh concrete to a previously poured section that has already set. Construction joints are necessary when a substructure unit is too large to pour in one continuous operation or when rain, equipment problems, or other conditions interrupt the pour. Unless construction joints are specifically called for on the plans, the contractor has to have written permission to use them. Some joints, however, may be described on the plans as “Optional”, and can be used at the contractor’s discretion. In addition, the contractor may request the relocation or elimination of construction joints. Such a change has to be approved by the Engineer.

To make a construction joint, either planned or unplanned, the contractor must form a raised keyway or keyways in the section to be poured later. After the first section has hardened, its surface is swept clean with wire brooms and kept wet. If a *Type A construction joint* is specified, the surface is notched between the reinforcement. Immediately before the fresh concrete is placed, the contractor draws the forms up tight against the concrete in place. To improve the bond between the sections, the contractor may apply a bonding epoxy to the exposed surface before resuming the pour.



To resist shear and other forces, construction joints in footings and in abutments for arch bridges have to be vertical; horizontal construction joints are used in walls and columns. Joints that will be exposed to view must be constructed carefully – straight, clean, and watertight. This is usually accomplished by finishing the concrete up the underside of a straight and level strip of wood that’s nailed to the form at the proper elevation. No construction joint should be made in areas where the reinforcing steel has been spliced. Section 702.15 of the Specifications gives all the requirements for the use of construction joints; Sheet 7245-BJTS-01 of the Standard Drawings for Bridges provides additional details.

During the pour, care must be taken not to disturb the position of any reinforcing steel that will be used to tie the section being poured to a section that will be poured later. If the bars are displaced, they should be re-tied immediately in the proper position. Concrete that is splashed on these bars has to be cleaned off before the next section is poured to insure a good bond. If the steel will be exposed to the weather for some time after the pour, it may have to be coated with a cement paste or equivalent to prevent it from rusting.

Special Cases

The placement of concrete in footings, under water, and for foundation seals involve techniques outside the general rules given above. For a complete explanation of the methods and requirements, see Section 702.20(d-f).

Finishing Concrete Surfaces

Unless otherwise authorized, the surface of the concrete shall be finished immediately after form removal. Only the minimum amount of covering necessary to allow finishing operations to be carried on shall be removed at one time. Subject to approval, metal ties may be left in the concrete for the purpose of supporting or bracing subsequent work. Such ties shall be in accordance with 702.12(b) and shall be of a type which uses a cone and rod as both spreader and tie. Before final acceptance of the work, the cones shall be removed and the cavities filled, in accordance with 702.12(b).

All concrete surfaces shall be given a finish immediately following the removal of any forms.

The concrete surfaces of pier and bent caps, the front face of mudwalls, and any other concrete surfaces specified shall be sealed. The material used for sealing shall be in accordance with 709. It shall be applied so as to obtain a finished film thickness of at least 250 µm (10 mils). Mixing, surface preparation, and method of application shall be in accordance with the manufacturer's recommendations. However, the surfaces to be sealed shall be prepared in accordance with 709 prior to applying the sealer.

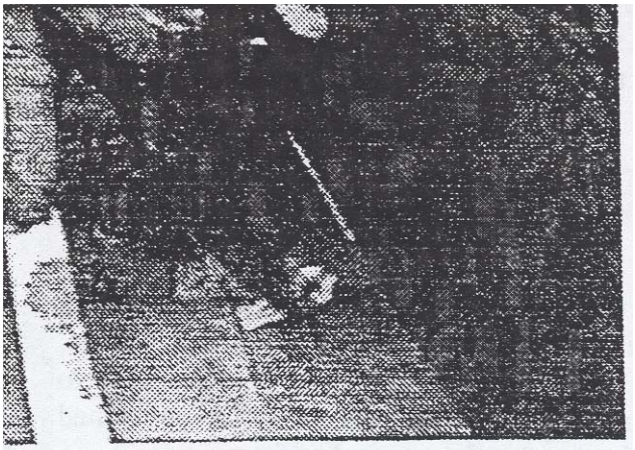
At the time of the removal of forms, the concrete surface shall be scraped to remove all fins and irregular projections. The surface shall then be power ground to smooth all joints and chamfers.

After grinding is completed, a paste of grout shall be applied to the concrete surface with a sponge float to fill all air holes and small irregularities. The paste grout shall be 6 parts of pre-mix mortar mix for masonry and 1 part white portland cement in accordance with ASTM C-150, Type 1.

After the paste grout takes its initial set, the surface of the concrete shall be scraped with a steel drywall knife to remove the paste from the surface.

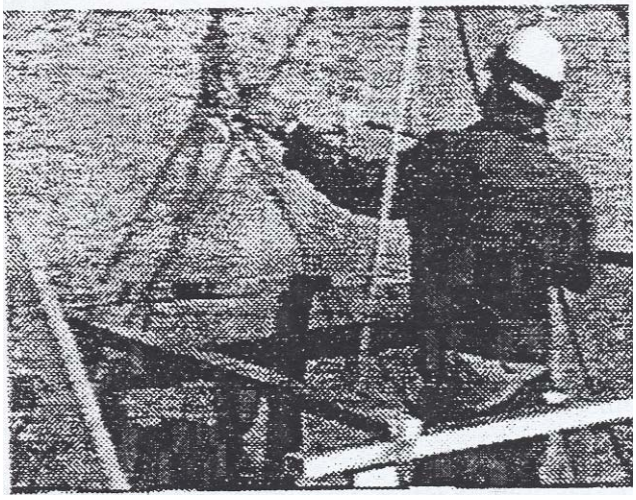
Finishing Bearing Areas

The bridge seats and areas in between require special treatment at the finishing stage. The tops of the bridge seats must be finished at exactly the right elevation and need to be completely level to insure full contact with the bottom of the bearing device. The areas in between the bridge seats must be sloped or crowned slightly to insure adequate surface drainage. Both results are obtained through proper finishing techniques.



Other Surface Treatments

The plans or Special Provisions will provide for the use of surface treatments other than the three classes of concrete finishes. For example, the plans may require the contactor to leave a rough surface texture of exposed aggregate. This can be accomplished by blasting off the surface mortar with a high-pressure water hose as shown here.



The surfaces of pier and bent caps, the front face of mudwalls, and any other areas specified have to be sealed against moisture penetration with an approved concrete sealer. The surfaces to be sealed must be sandblasted to remove form oil and other foreign matter and should be completely dry before the application. The sealant should be applied in a criss-cross pattern and achieve a thickness of 10 mils. No sealed surface should be rubbed. Section 709 of the Standard Specifications describes this operation in detail.

Curing Substructure Concrete

Once the concrete is in place it should be allowed to cure a certain amount of time to achieve its full strength. During the curing period, it's important that the concrete isn't placed under stress. The typical curing period for structural concrete is 96 hours after its initial set. The use of certain materials such as fly ash or Portland-pozzolan cement in the concrete will increase the curing period to 120 hours.

The Specifications describe two methods of curing concrete. The first is called the *protective covering* curing method. This method involves covering the surfaces to be cured with canvas, straw, burlap, sand, or other approved material and keeping it wet with water throughout the curing period. The water prevents the concrete from drying out too quickly. Surfaces that require a Class Two

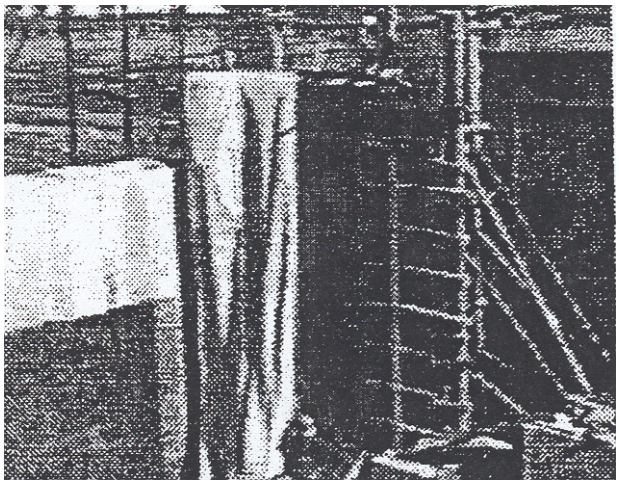
rubbing finish will have to have the protective covering temporarily removed to allow the rubbing to continue, but the covering should be restored as soon as possible.

The other curing method involves the use of a membrane forming *curing compound*. The curing compound may be applied after the concrete surface has received the specified finishing treatment. Up until then, the concrete should be protected by the protective covering method or, in the case of vertical surfaces, simply by leaving the forms in place.

Curing compound is applied at a minimum rate of one gallon for every 150 square feet of concrete surface. The application is done in two stages. The first coat is applied immediately after stripping the forms or upon acceptance of the concrete finish. The surface should be wetted with water, then coated with compound as soon as the water film disappears. The second application should begin after the first has set and according to the manufacturer's directions. During the curing operation, all untreated areas must be kept wet.

Finally, the plans may call for certain areas to be waterproofed. When the application of waterproofing material begins, curing of those areas is no longer required.

Cold Water Curing



In cold water weather (35 degrees and below), the contractor must keep the freshly poured concrete and the forms within a protective enclosure or covered with approved insulation material that is at least two inches thick. The air inside the enclosure or under the insulation has to be kept above 50 degrees for at least 72 hours. If for any reason the temperature drops below 50 degrees within the enclosure, the heating period has to be extended. When dry heat is used to maintain the required temperature, the contractor has to devise a means of providing enough moisture in the air within the enclosure to prevent the concrete from drying out too quickly. Heaters may be used to maintain the required temperature if the can provide continuous operation and the contractor has taken adequate fire-prevention and safety measures.

When rubbing the concrete is required, the forms must be removed and the rubbing performed during the protection period. Again, if this means that the concrete is exposed to temperatures below 50 degrees before the required 72 hours is up, the period of protection and heating must be extended.

Method of Measurement and Basis for Payment

Concrete is measured and paid for by the cubic yard placed in accordance with the plans or as directed. Forms, falsework, and other miscellaneous items need to complete the work are not paid for separately; the costs for those items are included in the costs of the concrete.